STATE OF CALIFORNIA
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT

LABORATORY TEST METHODS TO ESTABLISH THICKNESS FOR PAVEMENT SECTIONS BASED ON STABILOMETER AND EXPANSION PRESSURE MEASUREMENTS

Revised June 1953

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- Techniques
- Stb - Design

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
Division of Highways
MATERIALS AND RESEARCH DEPARTMENT
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INTRODUCTION

DESIGN METHOD TO ESTABLISH THICKNESS FOR PAVEMENT SECTIONS BASED ON STABILOMETER AND EXPANSION PRESSURE MEASUREMENTS

The object of the Stabilometer test when applied to soils or base materials is to determine the resistance to plastic deformation, hereafter designated simply as the Resistance or "R" value. The soil test specimen is formed in a manner that is intended to represent the worst condition, i.e. lowest density and highest degree of moisture saturation which it may reach after it is in place on the road. When the "R" value for the worst condition is known it is then possible to determine how thick the courses must be above the soil in question so that failure due to plastic flow of the soil will not occur under traffic.

It is generally impossible to predict whether the material forming a given subgrade will ever reach saturation or not, but as a design premise we assume that the void space in all soils being tested will become filled with water sooner or later. For this reason the Stabilometer test is made on saturated soils. (Saturation does not necessarily mean a plastic "sloppy" or a muddy condition of the soil).

In addition to the moisture content two other conditions must be developed in the test specimen before it will be in a condition to simulate the soil in place in the road. First, it must be compacted to a typical density or dry weight per cu. ft. which in turn establishes the initial moisture content that will saturate (fill) the void space, and second, the soil grains and coarse particles must have the proper placement or arrangement in the specimen. Two "identical" specimens compacted by different methods may have the same moisture content and density, yet have entirely different "R" values if the soil grains do not have similar structural arrangements with respect to one another. In the laboratory the particle arrangement is accomplished by a special compacting machine which gives the specimen a kneading action rather than a direct static load, and produces a test specimen that resembles the condition of materials compacted on the road by construction equipment and subsequent traffic.

Therefore, the three most important requirements which the test specimen should meet are degree of saturation, proper density, and proper contact pressure between the particles. Of these, particle orientation and arrangement is taken care of by the compactor, but additional steps are necessary in order to determine what ultimate in-place density should be expected after the road has been under traffic for a period of time and how much moisture will be required to produce saturation at that density.

Many granular soils could be prepared for testing merely by adding varying amounts of water to a series of samples, tamping them into cylindrical molds and then compressing under a confining load until water is exuded, showing saturation. The specimen showing saturation under a compression reproducing the compaction it would receive in the field during construction might be assumed to be the one which would have the "proper density" and give the correct "R" value.

However, most soils, especially clays, have a tendency to take up more water even after reaching saturation. The additional water must enter by expanding the soil mass often with considerable force and a reduced density corresponding to the higher moisture content. This results in a marked lowering of the "R" value. In such soils water will be taken up until the tendency to expand, (expansion pressure) is exhausted or balanced by the confining pressure, which is the pressure due to the weight of the layers above. Therefore, the ultimate equilibrium "R" value of the soil in the roadbed depends on the weight of the layers above, and the thickness of these layers which is necessary to prevent plastic flow or deformation under vehicle wheel loads in turn depends on the "R" value.

In order to find the correct final density for the soil or base material a series of specimens are prepared at different moisture contents and after they are compressed to the point where the water just fills the voids (saturation) they are tested for expansion pressure by confining them under a spring steel bar (in a special device) and measuring the deflection of the bar due to pressure developed in the soil when additional water is available. Thus the expansion pressure is measured without permitting the specimen to expand appreciably. After sixteen hours in the expansion pressure measuring device the "R" value of each saturated specimen is determined by means of the stabilometer.

The next step is to determine the thickness of cover indicated by each specimen in the condition in which it was tested. The theoretical thickness (weight) required to counteract the expansion pressure is determined, and the thickness required to carry the traffic load as indicated by the design chart is found for each "R" value. The thickness values from the expansion pressure are plotted against those from the "R" values for each test specimen in the series and the point on the curve where the two thicknessess are identical will be the minimum that will satisfy both factors. In other words the thickness that is necessary to support traffic loads when the soil soaks up a certain amount of water is also the thickness (weight) that will prevent the soil from taking up any more water, i.e. becoming more unstable. The soil is in equilibrium with the environment.

PREPARATION OF MATERIALS TO BE TESTED FOR "R" VALUE

Apparatus

(a) Water Spray and Turntable
(b) Scales, 5 Kg capacity, accurate to one gram
(c) Mixing Pans, Trowel, 1/2 gallon cans
(d) Quartering Splitter

Procedure - Normal

1. (a) Air dry the material and break down all clay and soil lumps until they will pass the #4 screen. All fine material should be broken loose from coarse material.

(b) Grade and separate the sample into the following sizes:

1. Retained 1"
2. Passing 1" retained 3/4"
3. Passing 3/4" retained 3/8"
4. Passing 3/8" retained #4
5. Passing #4

(c) If 75% or more of the sample passes the 3/4" sieve, as received, scalp the sample on the 3/4" sieve, otherwise, scalp on the 1" sieve.

(d) Quarter all passing #4 material to approximate quantities needed for each specimen.

(e) Recombine sample according to grading, weighing out four 1200 gram samples. Use a sample ticket with each sample. It is convenient to use colored tickets when cement or lime is added because these samples must be cured after they are compacted.

(f) Weigh out an extra sample of 200 grams or more having exactly the same grading as the others for the determination of initial moisture. Determine the moisture content by weighing accurately before and after drying to constant weight at 110°C.

(g) While mixing each of the 1200 gram samples with a hand trowel, add to each sample, using a fine water spray, approximately 1/2 to 2/3 the amount of moisture necessary to saturate the sample. Continue mixing for one minute. Record amount of water added and place each sample of mixed, loose material in a covered container and allow to stand overnight.

(h) Next day add additional moisture by use of the water spray until the estimated saturation moisture is reached. Mix well while adding water and continue mixing for one minute thereafter.

The "R" value test requires the preparation of four test briquettes at different moisture contents. The first briquette is used as a pilot specimen. After completing the pilot specimen, it can be used as a guide in the preparation of the other three stabilometer specimens which should, when possible, conform to the following limitations.

Height = 2.5 $\pm$ 0.1 inches

Exudation pressure - one sample should be above and two below 400 psi or 2 above and one below 400 psi

All samples should exude moisture between 100 and 800 psi, except when very high expansion pressures are expected. Wetter specimens are sometimes necessary to get low expansion pressures.

By estimating the weight of material and moisture needed a pilot or trial briquette is fabricated and its exudation pressure and height measured. Then, from the attached chart (Fig. 1) the correct weight of material for a 2-1/2" stabilometer specimen can be determined, using the pilot specimen data. From the exudation pressure of the pilot specimen determine whether to use more or less water in the remaining samples to obtain the desired results. If the pilot specimen conforms to the requirements for a stabilometer specimen it may be used as such, otherwise, it should be discarded.

2. (a) Samples to which Portland cement or lime is added in the laboratory are prepared in the same manner but are allowed to cure in a moisture cabinet for six days after compaction. The sample mold should be turned so that the specimen is in the top of the mold while curing and covered with a small pan to prevent an accumulation of water.

(b) Samples which contain cement or lime at the time of sampling (field samples) should not be cured. Rock over 3/4" in size should be removed and the remainder of the material should be tested the same as untreated soil. A sieve analysis is not normally made on samples containing cement.

(c) The amount of cement or lime is expressed as a percentage of the dry weight of soil.

3. (a) Samples containing asphalt, or oil cake, should have the lumps broken down to pass 3/4" sieve and all rocks over 3/4" removed.

(b) Quarter sample carefully and then follow normal procedure.

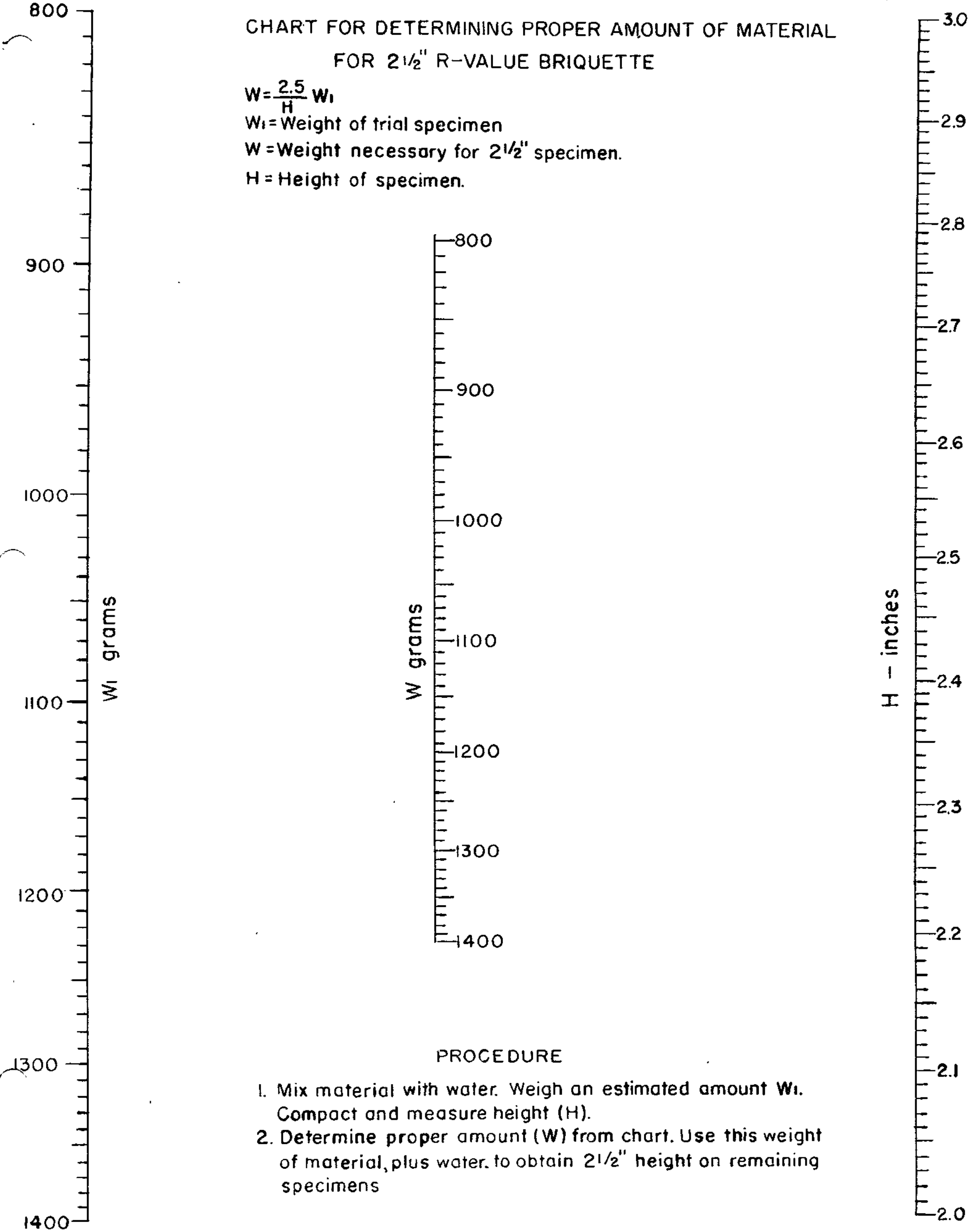
CHART FOR DETERMINING PROPER AMOUNT OF MATERIAL FOR 2½" R-VALUE BRIQUETTE

$$W = \frac{2.5}{H} W_1$$

W_1 = Weight of trial specimen

W = Weight necessary for 2½" specimen.

H = Height of specimen.



PROCEDURE

1. Mix material with water. Weigh an estimated amount W_1. Compact and measure height (H).
2. Determine proper amount (W) from chart. Use this weight of material, plus water, to obtain 2½" height on remaining specimens

STANDARD METHOD OF COMPACTION FOR MATERIALS TO BE TESTED FOR "R" VALUE

Scope

1. This compaction method covers all materials that are used in the design of Flexible Pavements.

Apparatus

2. (a) Mechanical Kneading Compactor

   (b) Compactor Accessories:

   4" dia. x 5" high Steel Molds, mold holder, mold funnel, 20" long feeder trough, spatula, rubber discs and phosphor bronze perforated discs, 4" dia. cardboard discs.

   (c) Basket Fabrication Equipment

Procedure ("R" Value)

3. (a) Place mold in mold holder that has a 4" dia. disc of 1/8" thick rubber cemented to plate. Adjust mold for 1/8" clearance beneath lower edge, clamp in place.

Place 4" dia. cardboard disc into mold on top of rubber disc. Put mold funnel in place and position the assembled mold holder on compactor turntable, locking it on studs.

(b) Place well mixed sample in feeder trough, distributing the loose material evenly along the full length.

(c) Start compactor and adjust the air pressure to 15 psi.

(d) Using spatula formed to fit the feeder trough, push the material in the lower three inches of the trough into the mold to cover the bottom. Push the remainder of the sample into the mold in 20 equal parts using one part for each blow of the compactor. Allow ten additional blows to level and seat the material. Raise compactor foot and clean. Place rubber disc 4" dia. 1/8" thick on top of specimen. (During the feeding operation if the soil pushes up around the foot markedly, lower the air pressure below 15 psi to a pressure that will reduce the pushing up).

(e) Lower compactor foot and immediately increase air pressure to a previously determined gauge reading that will give a compactor foot pressure of 350 psi. (Normal range = 21 - 24 psi) On compactors that are so equipped, the green indicator light will flash on when the exact foot pressure of 350 psi is reached.

(f) Apply 100 tamps to the specimen.

4. (a) Clays and clean sands may require lower compaction pressures. In these cases use the greatest compaction pressure possible, but do not allow the foot to penetrate over 1/4" into the surface of the specimen after all the material is in the mold.

5. (a) If free water should appear around the bottom of the mold during compaction, stop the compactor immediately and note the number of tamps.

(b) If the surface is left uneven by the action of the tamping foot, level the tamped surface with a 1-1/2 inch diameter flat ended compaction rod.

6. (a) Some granular materials are very difficult to handle without damage and may require a paper basket to keep the specimen intact. Baskets prevent the specimen from falling out of the mold and prevent crumbling when the specimen is transferred from the mold to the stabilometer. They are designed to restrain the specimen as little as possible during the stabilometer test. For that reason very few staples are used in constructing them.

(b) When compacting a specimen in a basket place all of the soil in the mold before lowering the foot. Use 100 tamps and then remove mold from the compactor. The mold should be kept upright so that the specimen will not fall out.

(c) The decision whether to use baskets on a given material must be based on experience. They should not be used if they are not needed. If baskets are not used and the specimen breaks up while being transferred into the stabilometer the fact may not be apparent at the time, but it will result in too high stabilometer pressure readings and <u>excessive displacement readings</u>. Both of these errors tend to lower the "R" value, with the result that the "R" values on the sample will be too low and a group of three tests will be erratic with respect to one another. When this happens the test must be repeated using baskets.

(d) Procedure for making baskets.

Materials: Basket making device equipped with 1/2 inch masking tape. Strips of notched paper. Phosphor - bronze perforated discs. The discs are the same as those used for the exudation pressure test.

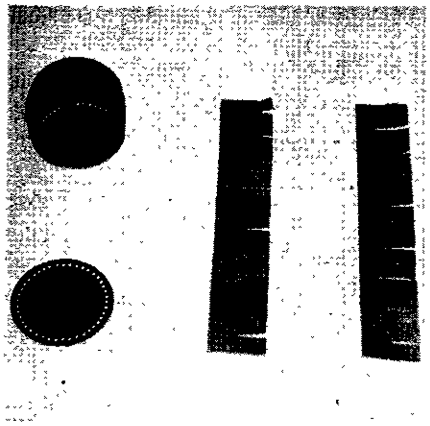
Procedure: (See the attached illustrations)

1. Staple ends of first piece of paper together. Overlap the ends to the first cut in the paper. Uncut edge is toward the stapler.

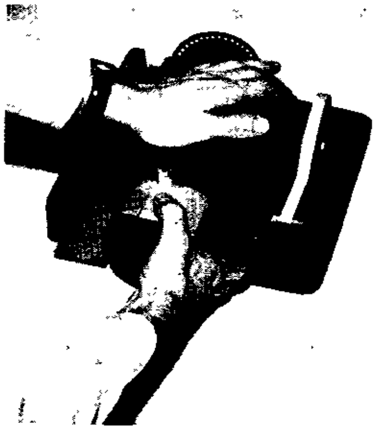
2. Rotate the paper slightly to offset the staple and slide toward stapler so that uncut edge is 2-1/2 inches from edge of wood. Two or more nails driven part way in will serve to position the paper. Place the second paper over the first with the cut edge toward the stapler, the uncut edge flush with the edge of the wood and the cuts on the two papers offset.

3. Place two more staples at third points to tie the papers together. A total of only four staples are used in the entire basket. Any more than this will confine the specimen unnecessarily.

4. Tape an exudation pressure disc in place to form the bottom.

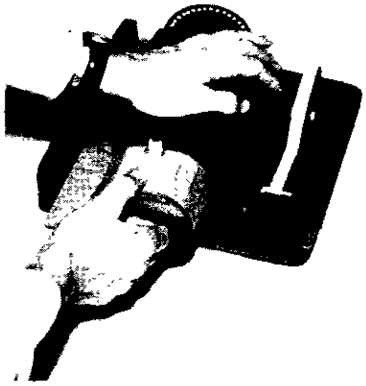


Basket and Parts



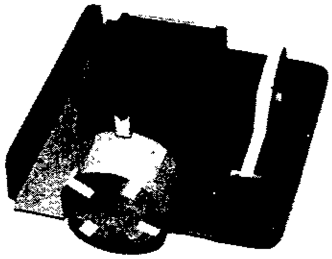
Step #1

Step #2



Step #3

Step #4



Completed Basket

DETERMINATION OF EXUDATION PRESSURE

Scope

1. This method is intended for use in determining the Exudation Pressure of "R" value test specimens of Untreated Subgrade materials such as bases, subbases and basement soils. This method is also used in determining the Exudation Pressure of cement treated bases and lime treated bases.

Apparatus

2. The apparatus shall consist of the following:

(a) Moisture Exudation Indicating device.

(b) Phosphor Bronze, Disc, Perforated edge, 4" dia. 28 gauge.

(c) Filter Paper, 4" dia. BKH Qualitative, Catalogue #28310 or equivalent.

(d) 10,000 lb. capacity testing press.

(e) 4" outside dia. x 6" follower ram

Procedure

3. (a) Place Phosphor Bronze Disc directly on tamped surface of specimen in mold followed by a single piece of filter paper.

(b) Invert mold with sample so that the filter paper is on the bottom and place mold on the contact plate of the Moisture Exudation Indicator making sure that it is centered firmly against both spring posts. In the case of a basket sample, do not invert the sample prior to placing on contact plate. Just put a filter paper on the bronze disc and put the mold on the contact plate.

Place contact plate with sample mold on platen of press centering assembly to insure even loading. Turn Moisture Exudation Indicator switch on. When mold is clean and in the correct position the center indicator light will be on.

(c) Place follower ram on top of sample and force sample down in the mold to contact plate, either by hand pressure or by using the press.

(d) With the testing press apply a load at the rate of 2000 lbs. per minute until five of the six outer lights are on. The vertical load, in psi, when the fifth goes on is taken as the exudation pressure.

If three outer lights are on and free moisture is visible around bottom of mold, the load in psi at this moment is taken as the exudation pressure.

(e) If the exudation pressure is found to be less than 100 or more than 800 psi the sample should be discarded, except in the case of very expansive material which may require an exudation pressure less than 100 psi.

(f) Samples to which cement or lime has been added in the laboratory are cured for six days after exudation pressure determination. All other samples including field samples of treated bases are tested next for expansion pressure. See T.M. No. 1-53 page 2, paragraph 2a.

Note - The batteries in the Moisture Exudation Indicating Device <u>must be replaced every 3 months</u> to insure efficient operation.

METHOD OF DETERMINING THE EXPANSION PRESSURE OF SUBGRADE MATERIALS

Scope

1. This method of test covers a procedure for determining the expansion pressure of subgrade materials by obtaining the pressure exerted against a calibrated bar, by a saturated sample in the presence of free water, while holding the volume practically constant.

Apparatus

2. (a) Expansion Pressure Device and small pans

   (b) 1/10,000" Dial Indicator Assembly, Allen wrench

   (c) Proving Ring (Headquarters Laboratory)

   (d) Filter Papers, 11 cm. BKH Shark Skin, Catalogue #28314 or equivalent

Procedure for Calibration

3. (a) Place dial indicator assembly in position on top of expansion pressure frame. The single bearing end must rest on adjustment plug.

(b) Place a 3/4" dia. ball bearing in the center hole of expansion pressure device turntable.

(c) Place Proving Ring (indentation down on 3/4" dia. ball) in expansion pressure frame, centering small ball on top of Proving Ring under expansion pressure dial contact.

(d) Rotate turntable up until Proving Ring Dial reads zero. Set adjustment plug so that expansion pressure dial reads zero.

(e) Increase pressure in steps of .0010" from 0 to .010" on expansion pressure dial. The expansion pressure dial must check the Proving Ring Dial within a tolerance of ± .0002" at every point.

(f) If the dials do not check within the above tolerance, loosen the top frame bar and adjust the position of the shims, between frame and spring steel bar, until the desired check is obtained.

Note - Keep top bar clean and polished. Calibrate instruments bi-monthly.

Procedure (Testing)

4. (a) Clean off all dust and foreign material from the spring steel bar and adjustment plug.

(b) Place dial assembly in position on top bar of expansion pressure frame. The single bearing end must rest on the adjustment plug.

(c) Using an Allen wrench raise or lower the adjustment plug so that the large dial indicator is on .0090".

(d) Take gross and tare weights of sample for density determination.

(e) Place perforated brass plate with rod on top of sample.

(f) Place mold on turntable over a filter paper on turntable.

Seat perforated brass plate firmly on specimen with pressure applied from fingers.

(g) Turn table up until the large dial indicator is on zero.

(h) Read and record height for density determination.

(i) Pour approximately 200 ml. of water on specimen in mold and allow to stand, undisturbed, for 16 hours or more.

(j) Read and record dial reading. Remove mold with specimen, and drain off excess water. Return any water that drained through and allow the specimen to begin percolating again before pouring off excess water.

(k) Record whether water drained freely through the specimen into pan below.

STABILITY OR STABILOMETER "R" VALUE DETERMINATION BY MEANS OF THE STABILOMETER

Scope

1. This method of test covers the procedure for determining Resistance Value "R", by means of the stabilometer. The stabilometer measures the transmitted horizontal pressure (P_h) that is developed in a test specimen by applying a given vertical pressure (P_v).

Apparatus

2. (a) Stabilometer and accessories.

(b) Testing Press, 10,000 pound capacity, minimum.

Calibration Procedure

3. (a) Adjust bronze nut on base of stabilometer so that an effective height of 2.4" of the test specimen is obtained when the stabilometer shell is in position on the base. The effective height is defined as that depth of the test specimen which acts against the liquid phase of the stabilometer. The "ideal" specimen is 2.5" high and has an effective height of 2.4".

(b) Adjust the testing press to give a constant movement of 0.05" per minute.

(c) With dummy specimen in place in the stabilometer apply a vertical load of 1000 pounds. Turn the pump to a pressure of exactly five psi. Adjust the turns indicator dial to zero. Turn pump handle at approximately two turns per second until the stabilometer dial reads 100 psi. The turns indicator dial shall read 2.00$\pm$ .05 turns. If it does not, the air in the cell must be adjusted. Remove air or add air by means of the rubber bulb and repeat the displacement measurement after each air change until the proper number of turns is obtained. Release horizontal and vertical pressures and remove dummy specimen. Stabilometer is now ready for testing specimens.

Note - Hydraulic presses must be run several minutes before oil warms sufficiently to maintain a constant speed.

4. (a) Force specimen to be tested into stabilometer. Specimen shall be well seated on top of base. Place follower on top of specimen, adjust pump to give a horizontal pressure of exactly five psi. Begin application of a vertical load to the test specimen.

(b) ("R" Value) Samples

Record the stabilometer gauge reading when the vertical pressure is 80 and 160 pounds per square inch. For a 4" specimen, this is at applied vertical loads of 1000 and 2000 pounds.

(c) Stop the vertical load when it reaches 2000 pounds. Reduce the vertical load to 1000 pounds and lock testing press at this point. Open stabilometer valve (if used) and turn pump so that the horizontal pressure is exactly 5 psi. Set turns indicator dial to zero. Turn pump handle at approximately two turns per second until the stabilometer gauge reads 100 psi.

(d) The number of turns indicated on dial are recorded as the <u>displacement</u> of the specimen. The turn indicator dial reads in .001 inches with each 0.1 inch equal to one turn. Thus, a reading of 0.250 inches indicates that 2.50 turns were made with the displacement pump. This measurement is known as the displacement of the specimen.

5. (a) The stabilometer "R" value is then calculated from the following formula

$$R = 100 - \frac{100}{\frac{2.5}{D}\left(\frac{P_v}{P_h} - 1\right) + 1}$$

Where P_v = 160 psi

D = turns displacement reading

P_h = horizontal pressure (stabilometer gauge at P_v = 160 psi)

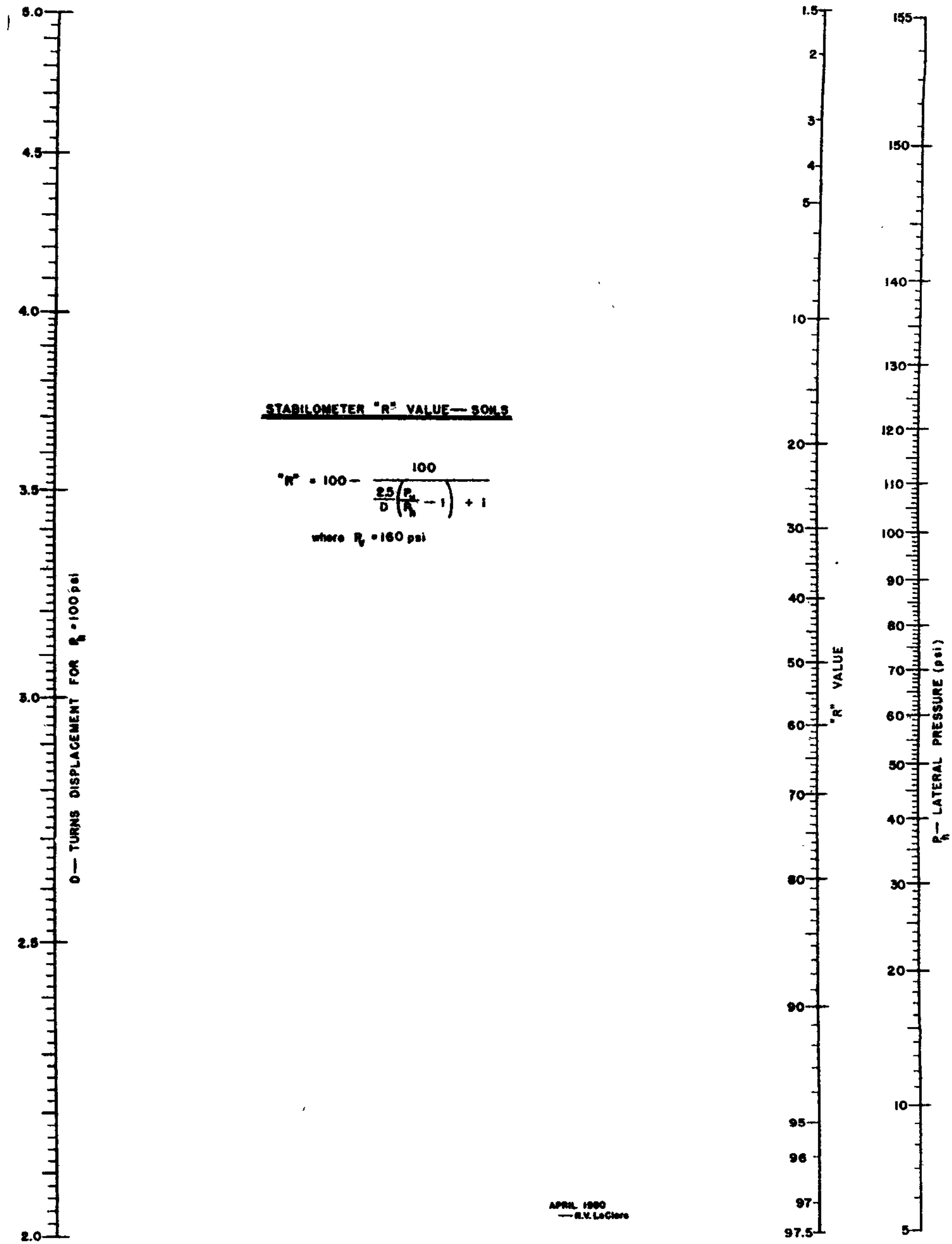
The attached stabilometer "R" value chart (Fig. 2) is normally used to solve the above formula.

6. (a) Every attempt should be made to fabricate test specimens having an over-all height between 2.4" and 2.6". However, if for some reason this is not possible, the stabilometer should be adjusted and the "R" value corrected as indicated on the accompanying chart (Fig. 3).

STABILOMETER "R" VALUE—SOILS

$$"R" = 100 - \frac{100}{\frac{2.5}{D}\left(\frac{P_v}{P_h} - 1\right) + 1}$$

where P_v = 160 psi



APRIL 1960
—R.V. LeClerc

FORM T 382

STATE OF CALIFORNIA DIVISION OF HIGHWAYS

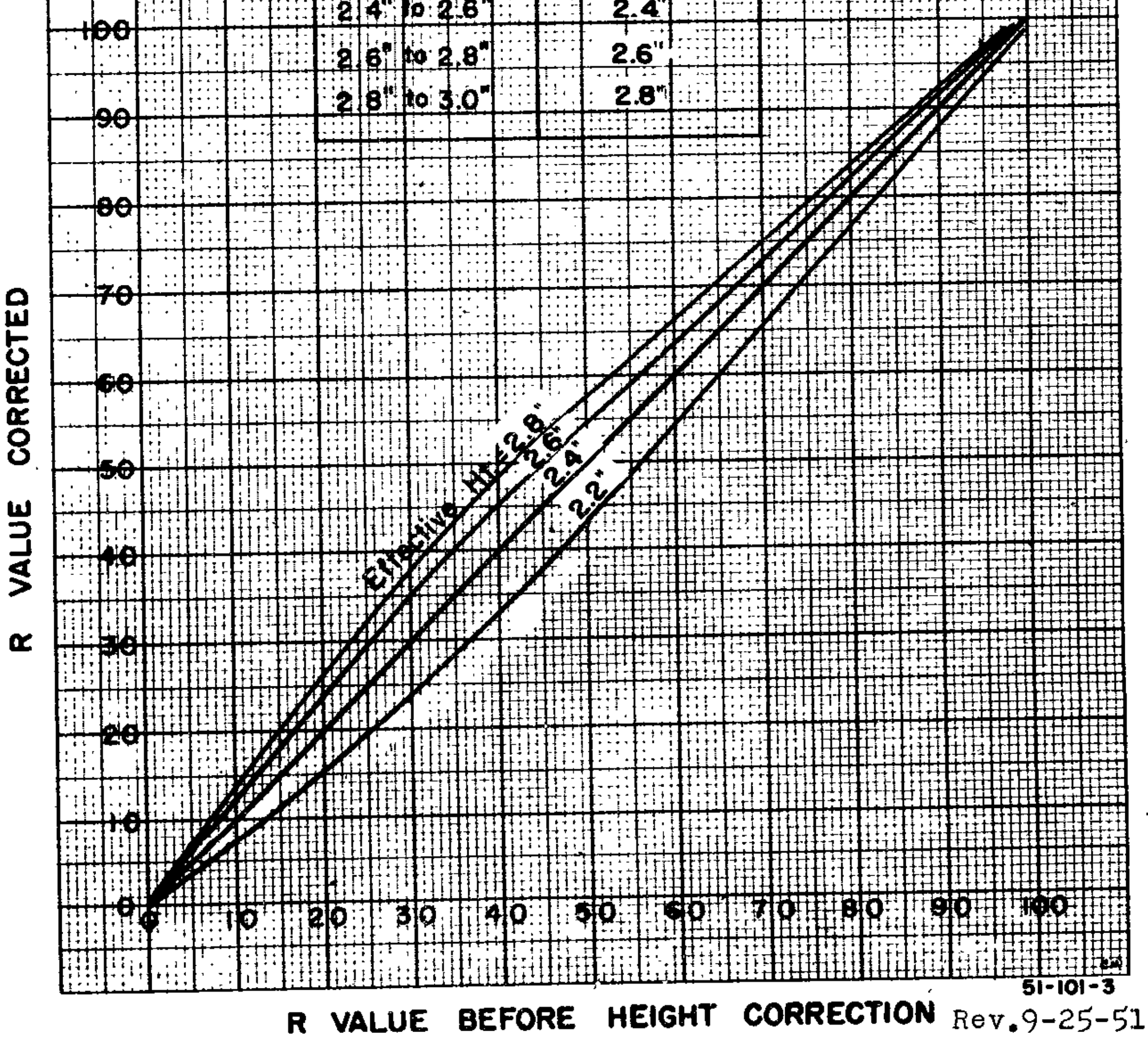
MATERIALS & RESEARCH DEPARTMENT

CHART FOR CORRECTING "R" VALUES TO EFFECTIVE SPECIMEN HEIGHT OF 240"

HEIGHT CORRECTION SHOULD BE MADE USING THE TABLE AND CHART BELOW

EXAMPLE: OVERALL HEIGHT OF 2.74", EFFECTIVE HEIGHT SET AT 2.6" R(UNCORRECTED) = 30; R(CORRECTED) = 35.

OVERALL SPECIMEN HEIGHT	EFFECTIVE HT.
2.2" to 2.4"	2.2"
2.4" to 2.6"	2.4"
2.6" to 2.8"	2.6"
2.8" to 3.0"	2.8"



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COMPUTATION OF DENSITIES FROM HEIGHT AND WEIGHT OF SPECIMENS

A. R Value Specimens

Total Moisture Content $M = M_1 + M_2$

M_1 = initial moisture content %
M_2 = percent moisture added

$$M_2 = W \frac{(100+M_1)}{W_1}$$

W = water added in ml.
W_1 = original weight in grams of soil to which water was added (1100, 1200 or 1300 gms.)

Density $D = \frac{30.3\ W_2}{(100+M)H}$ in lb per cu. ft. dry wt.

W_2 = wet wt. in grams after compaction but before expansion pressure test. The molds must be tared and weighed with the specimens.

H = Ht. of specimen in inches, normally measured on an expansion pressure device.

<u>EXAMPLE</u>

Test Specimen	A	B	C
Initial wt. of sample (W_1)	1200	1200	1200
Initial Moist. (M_1)	2.0	2.0	2.0
Water added, ml. (W)	60	75	85
Water added, %	$60(\frac{102}{1200})=5.1$	$75(\frac{102}{1200})=6.4$	$85(\frac{102}{1200})=7.2$
Moisture at compaction	2.0+5.1 =7.1	2.0+6.4 =8.4	2.0+7.2 =9.2
Ht., inches	2.52	2.49	2.50
Wet wt (W_2)	1175	1165	1170
Density	132	131	130

TEST RECORD AND THE METHOD OF CALCULATING THE DESIGN THICKNESS

Test Data Record

1. The right side of the word card "Laboratory Record of Tests made on Base, Subbase and Basement Soils", (Form T-361-53) is arranged for the recording of test data from the specimen tickets (Form T 328W-51) necessary to the R Value and density determinations. The following is a brief description of each item on the work card from the top down.

(a) Test specimens A,B, C etc. represent separate specimens tested, each having different degrees of moisture and density. For ease of plotting and interpretation, enter the specimen with largest exudation pressure under A and enter others in descending order of exudation pressure under B, C, etc.

(b) The date tested is normally recorded as the date the stabilometer phase (T.M. 5-53) of the R Value test is completed.

(c) Enter the compactor air pressure, in psi, used during the application of the 100 tamps. The normal value for 350 psi foot pressure varies between 21 and 24 pounds. Some clays cannot be compacted at full pressure and therefore the actual air pressure used should be recorded.

(d) The initial moisture is determined on a 200 plus gram sample having same grading ("as used") as the R Value specimens. The moisture sample is taken during the time the R Value samples are being batched (T.M. 1-53).

(e) Water added ml. includes the milliliters of water added for "soaking" plus the final water added during the mixing operation just prior to compaction (T.M. 6-53).

(f) Water added % is calculated as per T.M. 6-53.

(g) Moisture at compaction is the sum of the percent initial moisture and the percent moisture added.

(h) The height of briquette (to 0.01 inches) and the wet weight of briquette (grams) is determined prior to the expansion pressure test. These values are used with the moisture at compaction in the density computations (T.M. 6-53).

(i) The stabilometer data is entered as it is determined from the test. The "R" value for each specimen is calculated from this data using the alignment chart in Figure 2 or a special slide rule (T.M. 5-53).

(j) The exudation pressure is recorded as the compressive stress in psi at which moisture is exuded from the specimen as indicated by the exudation pressure device (T.M. 3-53).

(k) In the space provided for expansion pressure, the deflection measurement of the calibrated bar in the expansion pressure device multiplied by 10,000 is entered and is called the "dial reading". Referring to the example given on the included work card, dial readings of 33 and 13 correspond to deflection measurements of 0.0033 and 0.0013 inches, respectively.

(l) To determine the thickness indicated by expansion pressure for each specimen on the basis of an assumed unit weight of 130 lbs. per cu. ft., it is only necessary to devide the above mentioned dial reading by 2*. If in special investigations, where more accurate information is available, it is desired to use a different unit weight, then the cover thicknesses may be determined from the chart in Figure 4.

Calculation of the Design Thickness

2. Before any computations for thickness of cover can be made, it is necessary to evaluate or assume (1) the cohesiometer value of the cover overlaying the material being tested, (2) and the traffic index of the section under consideration.

*For those who desire to determine the actual expansion pressure in psi, multiply the dial reading by 0.038.

Cover material includes subbase, base and surface courses when the basement soil is being considered. Cover would include only base and surface when the subbase material is being tested. Similarly, when the base is being evaluated, cover would mean the bituminous surface or pavement alone. If the cover consists of a single layer, the appropriate cohesiometer value may be selected from table 7-602.4 of the Division of Highways Planning Manual of Instructions. If the cover consists of multi-layer construction, the equivalent cohesiometer value may be determined from the procedure and formula given in Chart II. For convenience and record the thicknesses and type of each overlaying layer is entered on the work card along with the design cohesion value.

The next step is to estimate the traffic to be sustained by the road. This traffic estimate will be expressed in terms of the number of equivalent 5000 lb. wheel loads (EWL) in one direction to be expected during the 10 year period following construction. For the purpose of calculating thicknesses, the EWL is converted to traffic index by means of Chart II.

Knowing the cohesiometer value of the cover material and the estimated traffic index for the road, by means of the attached Design Chart (Chart II) or an appropriate slide rule constructed for the purpose, determine and record the "Thickness indicated by stabilometer" corresponding with the R Value of each specimen.

The R value by exudation pressure may be determined by either of the two following methods.

<u>Method (a)</u> Plot the thickness indicated by the stabilometer (inches) for each specimen against the corresponding exudation pressure on the graph provided on the reverse side of the work card (see example). Determine the thickness at the intersection of the curve connecting the points with the 400 psi line and convert to R value using the design chart or slide rule.

<u>Method (b)</u> On the same graph plot the R value for each specimen against the corresponding exudation pressure. Record R value at the point where the curve crosses the 400 psi line.

The determination of the R value by expansion pressure is accomplished by first plotting thickness indicated by the stabilometer against thickness indicated by expansion pressure on the graph provided on the back of the work card (see example). Then note the thickness value at which the curve connecting the points crosses the 45 degree balance line. Convert this thickness to R value with the design chart or slide rule and record.

The R value at equilibrium is established by taking the lowest value of the above two R values. From this the design or indicated minimum thickness of cover for the above conditions is determined as before from the design chart or slide rule.

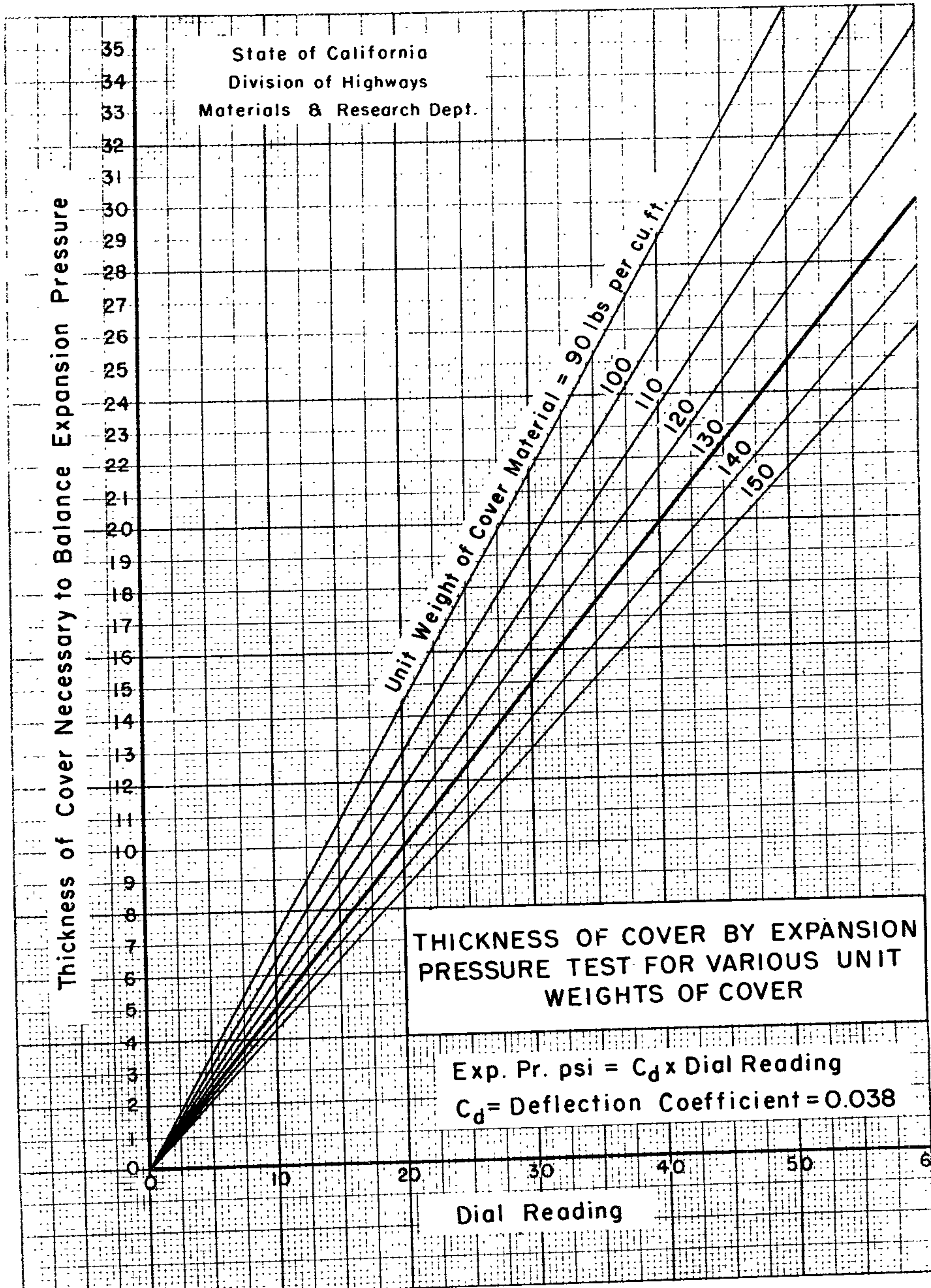

State of California
Division of Highways
Materials & Research Dept.
Thickness of Cover Necessary to Balance Expansion Pressure
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Unit Weight of Cover Material = 90 lbs per cu. ft.
100
110
120
130
140
150
THICKNESS OF COVER BY EXPANSION PRESSURE TEST FOR VARIOUS UNIT WEIGHTS OF COVER
Exp. Pr. psi = C_d x Dial Reading
C_d = Deflection Coefficient = 0.038
0
10
20
30
40
50
60
Dial Reading

Figure 4

CALCULATIONS FOR COMBINING MATERIAL TO MEET SPECIFICATIONS

Procedure

1. (a) Single Samples

To compute the "as used" grading, increase to 100% passing the size on which the sample is scalped and increase the percent passing other sizes in the same proportion.

For example a sample has 90% passing 3/4", 80% passing 3/8", and 70% passing #4. This sample would be scalped on 3/4" and the "as used" grading would be:

Passing 3/4" 100% = 100

Passing 3/8" $\frac{100}{90} \times (80) = 89$

Passing #4 $\frac{100}{90} \times (70) = 78$

The percentage of material passing other screen sizes should be computed in a like manner.

On the back of the work card place the weight of each size for a 1000 gm. sample. This is done by multiplying the percent of each size as used by 10. For the example above, the weights would be:

	1000 gm. Sample		1200 gm. Sample
3/4 - 3/8 (100 - 89) x 10 =	110 gm	+ 20% =	132
3/8 - 4 (89 - 78) x 10 =	110 gm	+ 20% =	132
4 - dust (78 - 0) x 10 =	780 gm	+ 20% =	936

2. (a) Combined Samples

Two or more different materials may be combined, but the computations are the same. Label the proper columns on Form T-361 with the test numbers of the samples to be combined. Opposite the largest size in any of the samples place the percentages of the samples to be used. In any given column the percentage passing the other sizes will be reduced by the same proportion as the first size.

(b) In the case of a sample being combined with its crushed oversize the grading of the uncrushed portion needs no adjustment. The sum of the percentages passing any size gives the total percent passing in the combination. After the grading of the combination is computed scalp on 3/4" or 1" in the usual way. Note that the material is scalped after combining and not before.

To compute the batching weights in a scalped combination break down the percentages in the "as used" column into components furnished by the different samples and figure weights as before.

For example, combine samples #1 and #2 using 20% of Sample #2.

		As Received				As Used
Sieve Size	#1	80% #1	#2	20% #2	Comb.	Scalp on 3/4"
1"	100	80		20	100	
3/4"	90	72	100	20	92	100
3/8"	80	64	95	19	83	90
#4	70	56	90	18	74	80

Compute Components of the percentage as used

Sieve Size	#1	#2	Check
3/4"	$\frac{100}{92} \times 72 = 78$	$\frac{100}{92} \times 20 = 22$	78 + 22 = 100
3/8"	$\frac{100}{92} \times 64 = 70$	$\frac{100}{92} \times 19 = 21$	70 + 21 = 91
#4	$\frac{100}{92} \times 56 = 61$	$\frac{100}{92} \times 18 = 20$	61 + 20 = 81

Check the sum of the components against the "as used" column. They may disagree by 1% because fractions have been rounded off.

Finally compute the weight of each size needed to produce the combined sample.

Sieve Size	#1	#2
3/4 - 3/8	(78 - 70) X 10 = 80	(22 - 21) X 10 = 10
3/8 - #4	(70 - 61) X 10 = 90	(21 - 20) X 10 = 10
#4 dust	(61 - 0) X 10 = 610	(20 - 0) X 10 = 200

Note that the test specimen will actually contain 78% of sample #1 instead of 80%. This is because the scalping removed some of sample #1 and none of sample #2.

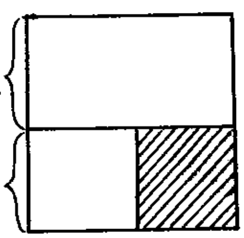
(c) Adjusting Gradings to fit specifications

This usually applies to combinations and is done by adjusting the percentages of the component samples by trial and error.

Adjustment may also be made by wasting a portion of the coarse or a portion of the fines in a sample. This method is as follows:

To waste a portion of passing #4:

Ret. #4



Pass. #4

W

Consider a unit amount of material
Let W = proportion to be wasted
P_1 = proportion passing #4 originally
P_2 = proportion passing #4 finally

$$P_2 = \frac{P_1 - W}{1 - W} \text{ from which } W = \frac{P_1 - P_2}{1 - P_2}$$

Example:

Sieve Size	Given % Passing	Specifications
3/4	100	95-100
3/8	90	
#4	70	55-65
#8	55	

To meet specifications it is necessary to reduce the amount of passing #4 material. Assuming that 60% is desired, then

$$W = \frac{.70 - .60}{1 - .6} = \frac{.1}{.4} = .25 \text{ or } 25\% \text{ of total sample}$$

The new grading will be

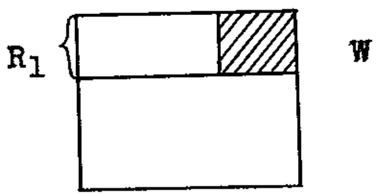
$$\text{Passing \#8} = \frac{60}{70} \times (55) = 47$$

$$\text{Retained } 3/8 = \frac{100-60}{100-70} \times (100-90) = \frac{40}{30} \times (10) = 13$$

$$\text{Passing } 3/8 = 100 - 13 = 87\%$$

Note that the new grading of the coarse material is computed by adjusting the percentages retained.

To waste a portion of retained #4:



Consider a unit amount of the material
Let W = proportion wasted
R_1 = Proportion retained #4 originally
R_2 = Proportioned retained #4 finally
P_1 = Proportion passing #4 originally
P_2 = Proportion passing #4 finally

$$R_2 = \frac{R_1 - W}{1 - W} \text{ from which } W = \frac{R_1 - R_2}{1 - R_2} = \frac{P_2 - P_1}{P_2}$$

Example: Given the following grading:

Size	% Passing
3/4	100
3/8	90
#4	70
#8	40

It is necessary to waste enough retained #4 to increase the passing #4 to 80%

Substituting into the above equation, $R_1 = 100-70 = 30$, $R_2 = 20$

$W = \frac{.30 - .20}{1 - .20} = \frac{.1}{.8} = .125$ or 12.5% of total

or $W = \frac{80 - 70}{80} = \frac{10}{80} = 12.5\%$

The new grading will be:

Passing #8 = $\frac{80}{70} \times (40) = 46\%$

Retained 3/8" = $\frac{20}{30} \times (10) = 6.7$

Passing 3/8" $100 - 6.7 = 93\%$

FORM T-361-53

LABORATORY RECC D OF TESTS MADE ON BASE, SUBBASE, AND BASEMENT SOILS

REC'D IN LAB. MA. 8, 1953
REC'D IN DEP'T MAR. 9, 1953
COMPLETED MAR. 16, 1953
CALCULATED BY GD
APPROVED BY GS
REPORTED MAR. 16, 1953

TEST No. 51-994 DIST. VII CO. LA RTE. 60 SEC. LA CONT. No. 51-7VC31-P

INSTRUCTIONS

GRADING ANALYSIS

SIEVE	AS RECEIVED	RET. CRUSHED	AS USED	SPECIF. LIMITS SOUGHT
1½	100			
1¼				
1	99			
¾	99		100	
½				
⅜	97		98	
4	96		97	
8	92		93	
16	86		87	
30	81		82	
50	74		75	
100	67		68	
200	60		61	
WASH	51		52	
5µ	19		19	
1µ	7		7	

GRADING AS USED WAS OBTAINED BY COMBINING SAMPLE

% BY WT. % BY VOL. TEST No. FIELD No.

TEST SPECIMEN	A	B	C	D	E	F	G
DATE TESTED	3-16	3-16	3-16				
COMPACTOR AIR PRESSURE P.S.I.	21	21	21				
INITIAL MOISTURE %	7.5	7.5	7.5				
WATER ADDED, ML	150	160	190				
WATER ADDED, %	14.8	15.7	18.8				
MOISTURE AT COMPACTION %	22.3	23.2	26.3				
HEIGHT OF BRIQUETTE	2.48	2.50	2.54				
WET WEIGHT OF BRIQUETTE	1009	1013	996				
DENSITY LB. PER CU. FT.	102	100	94				
STABILOMETER PH AT 1000 LBS.	39	46	60				
2000 LBS.	68	82	133				
DISPLACEMENT	3.00	3.15	3.20				
R-VALUE	53	43	14				
EXUDATION PRESSURE P.S.I.	600	450	170				
THICK. INDICATED BY STAB. INCHES	9.8	12.5	20.1				
EXPANSION PRESSURE	33	13	0				
THICK. INDICATED BY E.P. INCHES	16.5	6.5	0				

LABORATORY COMMENTS

SP. GR. FINES
SP. GR. COARSE
L.L. P.L.
P.I. SPECIF.
P.I. x % PASSING 200 SPECIF.
SAND EQUIVALENT 11 SPECIF.

SUBBASE
BASE 8" URB
SURFACE 4" PMS
COHESION VALUE 375
TRAFFIC INDEX 9.0
R-VALUE BY EXUDATION PRESSURE 39
R-VALUE BY EXPANSION PRESSURE 48
R-VALUE AT EQUILIBRIUM 39 SPECIF.

INDICATED MINIMUM THICK. OF COVER FOR ABOVE CONDITIONS 13.5"

EST. 8034. 77764 4-53 5M SPO

Test No.............. ....

WEIGHT SAMPLE	1000 gr.				1200 gr.			
Test No.								
1"								
1"-¾								
¾-½								
½-⅜	20				24			
⅜-4	10				12			
4-Dust	970				1164			

REMARKS

Spec.	
A	
B	
C	
D	
E	
F	
G